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MULTIPLICATIVE CONNECTIVITY STATUS NEIGHBORHOOD INDICES OF GRAPHS

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ABSTRACT

The connectivity indices are applied to measure the chemical characteristics of compounds in Chemical Graph Theory. In this paper, we introduce the multiplicative atom bond connectivity status neighborhood index, multiplicative geometric-arithmetic status neighborhood index, multiplicative arithmetic-geometric status neighborhood index, multiplicative augmented status neighborhood index of a graph. Also we compute these newly defined indices for some standard graphs, wheel and friendship graphs.

KEYWORDS: status neighborhood of a vertex, multiplicative connectivity status neighborhood indices, ABC, GA status neighborhood indices, graph.

Mathematics Subject Classification: *05C05, 05C12, 05C90.*

1. INTRODUCTION

A graph index is a numeric quantity from the structure of a molecule. There are different types of graph indices [1] such as distance based graph indices, degree based graph indices, spectral based graph indices. Among distance based graph indices, Wiener index [2], Harary index [3], status indices [4, 5] are studied well in the literature. Several status indices of a graph such as *ABC* and augmented status indices [6], *F*-status index [7], multiplicative (*a*, *b*)-status index [8], multiplicative first and second status indices [9], multiplicative *ABC*, *GA* status indices [10], status Gourava indices [11], multiplicative status indices [12].

Let *G* be a finite, simple, connected graph with vertex set *V*(*G*) and edge set *E*(*G*). The degree $d_G(u)$ of a vertex *u* in *G* is the number of vertices adjacent to *u*. The distance *d*(*u, v*) between any two vertices *u* and *v* is the length of shortest path connecting *u* and *v*. The status σ(*u*) of a vertex *u* in *G* is the sum of distances of all other vertices form *u* in *G*. The status neighborhood $\sigma_n(u)$ of a vertex *u* in *G* is the sum of status of the neighbors of *u*. We refer [13] for undefined term and notation.

In [14], Kulli introduced the first and second status neighborhood indices of a graph *G*, defined as

$$SN_1(G)=\sum_{uv\in E(G)}\left[\sigma_n(u)+\sigma_n(v)\right], \qquad SN_2II(G)=\sum_{uv\in E(G)}\sigma_n(u)\sigma_n(v).$$

Recently some variants of status neighborhood indices were studied, for example, in [15, 16].

Motivated by the work on status neighborhood indices, in [17] Kulli introduced the first and second multiplicative status neighborhood indices of a graph *G*, and they are defined as

$$SN_1II(G)=\prod_{uv\in E(G)}\left[\sigma_n(u)+\sigma_n(v)\right], \qquad SN_2II(G)=\prod_{uv\in E(G)}\sigma_n(u)\sigma_n(v).$$

We now propose some new status neighborhood indices as follows:

The multiplicative atom bond connectivity (*ABC*) status neighborhood index of a graph *G* is defined as

$$ABCSNII(G) = \prod_{uv\in E(G)} \left(\frac{\sigma_n(u)+\sigma_n(v)-2}{\sigma_n(u)\sigma_n(v)} \right)^{\frac{1}{2}}.$$

The multiplicative geometric-arithmetic (*GA*) status neighborhood index of a graph *G* is defined as

$$GASNII(G) = \prod_{uv\in E(G)} \frac{2\sqrt{\sigma_n(u)\sigma_n(v)}}{\sigma_n(u)+\sigma_n(v)}.$$

The multiplicative arithmetic-geometric (*AG*) status neighborhood index of a graph *G* is defined as

$$AGSNII(G) = \prod_{uv\in E(G)} \frac{\sigma_n(u)+\sigma_n(v)}{2\sqrt{\sigma_n(u)\sigma_n(v)}}.$$

The multiplicative augmented status neighborhood index of a graph *G* is defined as

$$ASNII(G) = \prod_{uv\in E(G)} \left[\frac{\sigma_n(u)\sigma_n(v)}{\sigma_n(u)+\sigma_n(v)-2} \right]^3.$$

The multiplicative symmetric division status neighborhood index of a graph *G* defined as

$$SDSNII(G) = \prod_{uv\in E(G)} \left(\frac{\sigma_n(u)}{\sigma_n(v)} + \frac{\sigma_n(v)}{\sigma_n(u)} \right).$$

Among degree based indices, the atom bond connectivity index, [18, 19, 20, 21, 22, 23], geometric-arithmetic index [24], augmented index [25] were studied in the literature.

In this paper, we determine the multiplicative atom bond connectivity status neighborhood index, multiplicative geometric-arithmetic status neighborhood index, multiplicative arithmetic-geometric status neighborhood index, multiplicative augmented status neighborhood index, multiplicative symmetric division status neighborhood index of complete, wheel and friendship graphs.

2. RESULTS FOR COMPLETE GRAPHS

In the following theorem, we compute the multiplicative atom bond connectivity status neighborhood index of K_n.

Theorem 1. The multiplicative atom bond connectivity status neighborhood index of a complete graph K_n is

$$ABCSNII(K_n) = \left[\frac{2n(n-2)}{(n-1)^4} \right]^{\frac{1}{4}n(n-1)}.$$

Proof: Let K_n be a complete graph with *n* vertices and $\frac{1}{2}n(n-1)$ edges. Then for any vertex *u* of K_n, $\sigma(u) = n - 1$. By calculation, we have $\sigma_n(u) = (n-1)^2$ for any vertex *u* of K_n. Therefore

$$ABCSNII(K_n) = \prod_{uv\in E(K_n)} \left(\frac{\sigma_n(u)+\sigma_n(v)-2}{\sigma_n(u)\sigma_n(v)} \right)^{\frac{1}{2}}$$

$$= \left[\frac{(n-1)^2+(n-1)^2-2}{(n-1)^2(n-1)^2} \right]^{\frac{1}{2}\times\frac{1}{2}n(n-1)} = \left[\frac{2n(n-2)}{(n-1)^4} \right]^{\frac{1}{4}n(n-1)}.$$

In the following theorem, we compute the multiplicative geometric-arithmetic status neighborhood index of K_n.

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Theorem 2. The multiplicative geometric-arithmetic status neighborhood index of K_n is

$$GASNII(K_n)=1.$$

Proof: For any vertex u of K_n, $\sigma_n(u) = (n-1)^2$. Therefore

$$GASNII(K_n)=\prod_{uv\in E(K_n)}\frac{2\sqrt{\sigma_n(u)\sigma_n(v)}}{\sigma_n(u)+\sigma_n(v)}$$

$$=\left[\frac{2\sqrt{(n-1)^2(n-1)^2}}{(n-1)^2(n-1)^2}\right]^{\frac{1}{2}n(n-1)}=1.$$

In the following theorem, we compute the multiplicative arithmetic-geometric status neighborhood index of K_n.

Theorem 3. The multiplicative arithmetic-geometric status neighborhood index of K_n is

$$AGSNII(K_n)=1.$$

Proof: For any vertex u of K_n, $\sigma_n(u) = (n-1)^2$. Thus

$$AGSNII(K_n)=\prod_{uv\in E(K_n)}\frac{\sigma_n(u)+\sigma_n(v)}{2\sqrt{\sigma_n(u)\sigma_n(v)}}$$

$$=\left[\frac{(n-1)^2+(n-1)^2}{2\sqrt{(n-1)^2(n-1)^2}}\right]^{\frac{1}{2}n(n-1)}=1.$$

In the following theorem, we derive the multiplicative augmented status neighborhood index of K_n.

Theorem 4. The multiplicative augmented status neighborhood index of a complete graph K_n is

$$ASNII(K_n)=\left[\frac{(n-1)^4}{2n(n-2)}\right]^{\frac{3}{2}n(n-1)}.$$

Proof: We have $\sigma_n(u) = (n-1)^2$ for any vertex u of K_n. Thus

$$ASNII(K_n)=\prod_{uv\in E(K_n)}\left(\frac{\sigma_n(u)\sigma_n(v)}{\sigma_n(u)+\sigma_n(v)-2}\right)^3$$

$$=\left[\frac{(n-1)^2(n-1)^2}{(n-1)^2+(n-1)^2-2}\right]^{3\times\frac{1}{2}n(n-1)}$$

$$=\left[\frac{(n-1)^4}{2n(n-2)}\right]^{\frac{3}{2}n(n-1)}.$$

In the following theorem, we compute the multiplicative symmetric division status neighborhood index of K_n.

Theorem 5. The multiplicative symmetric division status neighborhood index of K_n is

$$SDSNII(K_n)=2^{\frac{1}{2}n(n-1)}.$$

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Proof: For any vertex u of K_n, $\sigma_n(u) = (n-1)^2$. Therefore

$$SDSNII(K_n) = \prod_{uv\in E(K_n)} \left(\frac{\sigma_n(u)}{\sigma_n(v)} + \frac{\sigma_n(v)}{\sigma_n(u)} \right)$$

$$= \left[\frac{(n-1)^2}{(n-1)^2} + \frac{(n-1)^2}{(n-1)^2} \right]^{\frac{1}{2}n(n-1)}$$

$$= 2^{\frac{1}{2}n(n-1)}.$$

3. RESULTS FOR WHEEL GRAPHS

A wheel graph W_n is the join of C_n and K_1. A wheel graph W_4 is shown in Figure 1.

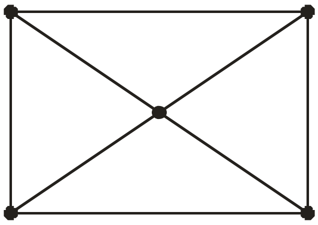

Figure 1. Wheel graph W_4

A wheel graph has n+1 vertices and $2n$ edges. In W_n, there are two types of status edges as follows:

$$E_1 = \{uv \in E(W_n) \mid \sigma(u) = \sigma(v) = 2n-3\}, \qquad |E_1| = n.$$

$$E_2 = \{uv \in E(W_n) \mid \sigma(u) = n, \sigma(v) = 2n-3\}, \qquad |E_2| = n.$$

By calculation, we obtain that there are two types of status neighborhood edges as given in Table 1.

Table 1. Status neighborhood edge partition of W_n

$\sigma_n(u), \sigma_n(v) \setminus uv \in E(W_n)$	$(5n-6, 5n-6)$	$(5n-6, n(2n-3))$
Number of edges	n	n

In the following theorem, we compute the multiplicative atom bond connectivity status neighborhood index of W_n.

Theorem 6. The multiplicative atom bond connectivity status neighborhood index of W_n is

$$ABCSNII(W_n) = \left(\frac{(10n-14)}{(5n-6)^2} \right)^{\frac{n}{2}} \times \left(\frac{2n^2+2n-8}{10n^3-27n^2+18n} \right)^{\frac{n}{2}}.$$

Proof: Let W_n be a wheel graph. From definition and by using Table 1, we deduce

$$ABCSNII(W_n) = \prod_{uv\in E(W_n)} \left(\frac{\sigma_n(u)+\sigma_n(v)-2}{\sigma_n(u)\sigma_n(v)} \right)^{\frac{1}{2}}$$

$$= \left(\frac{5n-6+5n-6-2}{(5n-6)(5n-6)} \right)^{\frac{1}{2}n} \times \left(\frac{5n-6+2n^2-3n-2}{(5n-6)(2n^2-3n)} \right)^{\frac{1}{2}n}$$

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$$=\left(\frac{10n-14}{(5n-6)^2}\right)^{\frac{n}{2}}\times\left(\frac{2n^2+2n-8}{10n^3-27n^2+18n}\right)^{\frac{n}{2}}.$$

In the following theorem, we determine the multiplicative geometric-arithmetic status neighborhood index of a wheel graph W_n.

Theorem 7. The multiplicative geometric-arithmetic status neighborhood index of W_n is

$$GASNII(W_n)=\left(\frac{\sqrt{10n^3-27n^2+18n}}{n^2+n-3}\right)^n.$$

Proof: Using definition and Table 1, we derive

$$GASNII(W_n)=\prod_{uv\in E(W_n)}\frac{2\sqrt{\sigma_n(u)\sigma_n(v)}}{\sigma_n(u)+\sigma_n(v)}$$

$$=\left(\frac{2\sqrt{(5n-6)(5n-6)}}{5n-6+5n-6}\right)^n\times\left(\frac{2\sqrt{(5n-6)(2n^2-3n)}}{5n-6+2n^2-3n}\right)^n$$

$$=\left(\frac{\sqrt{10n^3-27n^2+18n}}{n^2+n-3}\right)^n.$$

In the following theorem, we compute the multiplicative arithmetic-geometric status neighborhood index of a wheel graph W_n.

Theorem 8. The multiplicative arithmetic-geometric status neighborhood index of W_n is

$$AGSNII(W_n)=\left(\frac{n^2+n-3}{\sqrt{10n^3-27n^2+18n}}\right)^n.$$

Proof: From definition and by using Table 1, we obtain

$$AGSNII(W_n)=\prod_{uv\in E(W_n)}\frac{\sigma_n(u)+\sigma_n(v)}{2\sqrt{\sigma_n(u)\sigma_n(v)}}$$

$$=\left(\frac{5n-6+5n-6}{\sqrt{(5n-6)(5n-6)}}\right)^n\times\left(\frac{5n-6+2n^2-3n}{\sqrt{(5n-6)(2n^2-3n)}}\right)^n$$

$$=\left(\frac{n^2+n-3}{\sqrt{10n^3-27n^2+18n}}\right)^n.$$

In the following theorem, we compute the multiplicative augmented status neighborhood index of W_n.

Theorem 9. The multiplicative augmented status neighborhood index of a wheel graph W_n is

$$ASNII(W_n)=\left(\frac{(5n-6)^2}{(10n-14)}\right)^{3n}\times\left(\frac{10n^3-27n^2+18n}{2n^2+2n-8}\right)^{3n}.$$

Proof: Using definition and by using Table 1, we deduce

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$$ASNII(W_n)=\prod_{uv\in E(W_n)}\left(\frac{\sigma_n(u)\sigma_n(v)}{\sigma_n(u)+\sigma_n(v)-2}\right)^3$$
$$=\left(\frac{(5n-6)(5n-6)}{5n-6+5n-6-2}\right)^{3n}\times\left(\frac{(5n-6)(2n^2-3n)}{5n-6+2n^2-3n-2}\right)^{3n}$$
$$=\left(\frac{(5n-6)^2}{10n-14}\right)^{3n}\times\left(\frac{10n^3-27n^2+18n}{2n^2+2n-8}\right)^{3n}.$$

In the following theorem, we determine the multiplicative symmetric division status neighborhood index of W_n.

Theorem 10. The multiplicative symmetric division status neighborhood index of a wheel graph W_n is

$$SDSNII(W_n)=2^n\left(\frac{5n-6}{2n^2-3n}+\frac{2n^2-3n}{5n-6}\right)^n.$$

Proof: From definition and by using Table 1, we derive

$$SDSNII(W_n)=\prod_{uv\in E(W_n)}\left(\frac{\sigma_n(u)}{\sigma_n(v)}+\frac{\sigma_n(v)}{\sigma_n(u)}\right)$$
$$=\left(\frac{5n-6}{5n-6}+\frac{5n-6}{5n-6}\right)^n\times\left(\frac{5n-6}{2n^2-3n}+\frac{2n^2-3n}{5n-6}\right)^n$$
$$=2^n\left(\frac{5n-6}{2n^2-3n}+\frac{2n^2-3n}{5n-6}\right)^n.$$

4. RESULTS FOR FRIENDSHIP GRAPHS

A friendship graph F_n is the graph obtained by taking $n \geq 2$ copies of C_3 with vertex in common. A graph F_4 is shown in Figure 2.

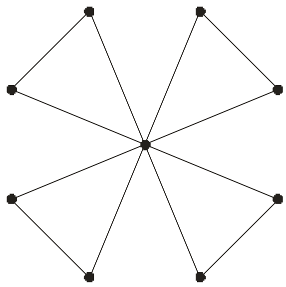

Figure 2. Friendship graph F_4

A graph F_n has $2n+1$ vertices and $3n$ edges. By calculation, we obtain that there are two types of status edges as follows:

$$E_1=\{uv\in E(F_n)\mid \sigma(u)=\sigma(v)=2n-3\}, \qquad |E_1|=n.$$
$$E_2=\{uv\in E(F_n)\mid \sigma(u)=2n, \sigma(v)=4n-2\}, \qquad |E_2|=2n.$$

By calculation, there are two types of status neighborhood edges as given in Table 2.

Table 2. Status neighborhood edge partition of F_n

$\sigma_n(u), \sigma_n(v) \setminus uv \in E(F_n)$	$(6n-2, 6n-2)$	$(6n-2, 8n^2-4n)$
Number of edges	n	$2n$

In the following theorem, we compute the multiplicative atom bond connectivity status neighborhood index of a friendship graph F_n.

Theorem 11. The multiplicative atom bond connectivity status neighborhood index of F_n is

$$ABCSNII(F_n) = \left(\frac{6n-3}{18n^2-12n+2}\right)^{\frac{n}{2}} \times \left(\frac{4n^2+n-2}{24n^3-20n^2+4n}\right)^{n}.$$

Proof: From definition and by using Table 2, we derive

$$ABCSNII(F_n) = \prod_{uv\in E(F_n)} \left(\frac{\sigma_n(u)+\sigma_n(v)-2}{\sigma_n(u)\sigma_n(v)}\right)^{\frac{1}{2}}$$

$$= \left[\frac{6n-2+6n-2-2}{(6n-2)(6n-2)}\right]^{\frac{n}{2}} \times \left(\frac{6n-2+8n^2-4n-2}{(6n-2)(8n^2-4n)}\right)^{\frac{2n}{2}}$$

$$= \left(\frac{6n-3}{18n^2-12n+2}\right)^{\frac{n}{2}} \times \left(\frac{4n^2+n-2}{24n^3-20n^2+4n}\right)^{n}.$$

In the following theorem, we determine the multiplicative geometric-arithmetic status neighborhood index of a friendship graph F_n.

Theorem 12. The multiplicative geometric-arithmetic status neighborhood index of F_n is

$$GASNII(F_n) = \left[\frac{\sqrt{48n^3-40n^2+8n}}{4n^2+n-1}\right]^{2n}.$$

Proof: Using definition and Table 2, we deduce

$$GASNII(F_n) = \prod_{uv\in E(W_n)} \frac{2\sqrt{\sigma_n(u)\sigma_n(v)}}{\sigma_n(u)+\sigma_n(v)}$$

$$= \left(\frac{2\sqrt{(6n-2)(6n-2)}}{6n-2+6n-2}\right)^{n} \times \left(\frac{2\sqrt{(6n-2)(8n^2-4n)}}{6n-2+8n^2-4n}\right)^{2n}$$

$$= \left[\frac{\sqrt{48n^3-40n^2+8n}}{4n^2+n-1}\right]^{2n}.$$

In the following theorem, we compute the multiplicative arithmetic-geometric status neighborhood index of a wheel graph F_n.

Theorem 13. The multiplicative arithmetic-geometric status neighborhood index of F_n is

$$AGSNII(F_n) = \left(\frac{4n^2+n-1}{\sqrt{48n^3-40n^2+8n}}\right)^{2n}.$$

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Proof: From definition and by using Table 2, we obtain

$$AGSNII(F_n) = \prod_{uv \in E(F_n)} \frac{\sigma_n(u)+\sigma_n(v)}{2\sqrt{\sigma_n(u)\sigma_n(v)}}$$

$$= \left[\frac{6n-2+6n-2}{2\sqrt{(6n-2)(6n-2)}}\right]^n \times \left[\frac{6n-2+8n^2-4n}{2\sqrt{(6n-2)(8n^2-4n)}}\right]^{2n}$$

$$= \left[\frac{4n^2+n-1}{\sqrt{48n^3-40n^2+8n}}\right]^{2n}.$$

In the following theorem, we determine the multiplicative augmented status neighborhood index of F_n.

Theorem 14. The multiplicative augmented status neighborhood index of a friendship graph F_n is

$$ASNII(F_n) = \left[\frac{18n^2-12n+2}{6n-3}\right]^{3n} \times \left[\frac{24n^3-20n^2+4n}{4n^2+n-2}\right]^{6n}.$$

Proof: Using definition and by using Table 2, we obtain

$$ASNII(F_n) = \prod_{uv \in E(W_n)} \left(\frac{\sigma_n(u)\sigma_n(v)}{\sigma_n(u)+\sigma_n(v)-2}\right)^3$$

$$= \left[\frac{(6n-2)(6n-2)}{6n-2+6n-2-2}\right]^{3n} \times \left[\frac{(6n-2)(8n^2-4n)}{6n-2+8n^2-4n-2}\right]^{6n}$$

$$= \left[\frac{18n^2-12n+2}{6n-3}\right]^{3n} \times \left[\frac{24n^3-20n^2+4n}{4n^2+n-2}\right]^{6n}.$$

In the following theorem, we compute the multiplicative symmetric division status neighborhood index of a friendship F_n.

Theorem 15. The multiplicative symmetric division status neighborhood index of F_n is

$$SDSNII(F_n) = 2^n \left(\frac{3n-1}{4n^2-2n} + \frac{4n^2-2n}{3n-1}\right)^{2n}.$$

Proof: From definition and by using Table 2, we deduce

$$SDSNII(F_n) = \prod_{uv \in E(F_n)} \left(\frac{\sigma_n(u)}{\sigma_n(v)} + \frac{\sigma_n(v)}{\sigma_n(u)}\right)$$

$$= \left(\frac{6n-2}{6n-2} + \frac{6n-2}{6n-2}\right)^n \times \left(\frac{6n-2}{8n^2-4n} + \frac{8n^2-4n}{6n-2}\right)^{2n}$$

$$= 2^n \left(\frac{3n-1}{4n^2-2n} + \frac{4n^2-2n}{3n-1}\right)^{2n}.$$

5. CONCLUSION

In this paper, we have introduced the multiplicative atom bond connectivity status neighborhood index, multiplicative geometric-arithmetic status neighborhood index, multiplicative geometric-arithmetic status neighborhood index, multiplicative augmented status neighborhood index, multiplicative symmetric division

status neighborhood index of a graph. We have determined these new indices for complete graphs, wheel graphs, friendship graphs.

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